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GATEWAY
MODELING AND SIMULATION PLAN

REVISION AND HISTORY PAGE

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Draft	-	Draft (draft version for Document Availability Authorization review)	09/18/19

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1.0 PURPOSE

This plan institutes direction across the Gateway Program and the Element Projects to ensure that Cross Program M&S are produced in a manner that (1) generate the artifacts required for NASA-STD-7009 compliance, (2) ensures interoperability of M&S exchanged and integrated across the program and, (3) drives integrated development efforts to provide cross-domain integrated simulation of the Gateway elements, space environment, and operational scenarios. This direction is flowed down via contractual enforcement to prime contractors and includes both the GMS requirements specified in this plan and the NASA-STD-7009 derived requirements necessary for compliance.

Grounding principles for management of Gateway Models and Simulations (M&S) are derived from the Columbia Accident Investigation Board (CAIB) report and the Diaz team report, "A Renewed Commitment to Excellence." As an outcome of these reports, and in response to Action 4 of the Diaz team report, the NASA Standard for Models and Simulations, NASA-STD-7009 was developed. The standard establishes M&S requirements for development and use activities to ensure proper capture and communication of M&S pedigree and credibility information to Gateway program decision makers.

Through the course of the Gateway program life cycle M&S will be heavily relied upon to conduct analysis, test products, support operations activities, enable informed decision making and ultimately to certify the Gateway with an acceptable level of risk to crew and mission. To reduce risk associated with M&S influenced decisions, this plan applies the NASA-STD-7009 requirements to produce the artifacts that support credibility assessments and ensure the information is communicated to program management.

1.1 EXECUTIVE SUMMARY

Four key topics are addressed in this document:

NASA-STD-7009 Compliance
To ensure Gateway program decision makers have complete understanding of cross-program MS capabilities and credibility for use, this M&S Plan implements the NASA-STD-7009 M&S requirements for the Gateway program. Capture and communication of compliance information is handled primarily through the Metadata described in Appendix C of this plan. The Gateway M&S plan includes (1) an incremental approach to compliance found in Appendix C of this plan and (2) a criticality-based tailoring of the NASA-STD-7009 requirements found in Appendix D.

M&S Roles and Responsibilities, Processes and Products
Defining the Gateway M&S System Manager role, establishing how L2 and L3 Element M&S activities and products will be coordinated and exchanged and defining how CP M&S dependencies will be identified and tracked are essential to program planning, successful cross-program M&S integration and ultimately to certifying the vehicle for flight. This plan defines key roles and responsibilities, processes such as criticality assessments and tailoring, and products including an M&S library with a maintained inventory and tools to enable effective M&S collaboration.

Data Exchange Requirements
To enable effective M&S collaboration across the Gateway program, data exchange mechanisms are defined in this plan to support run-time collaborative simulation and data and model exchange.

M&S Contract Deliverables
Cross-program M&S required for Gateway integrated design, test, verification, training and operations activities through the program life cycle are detailed in this plan so that they may be specified as contract deliverables. Required emulation capability, including design data, models and simulations, are described in this plan to ensure element contracts include schedule and resource allocations to complete these activities, meet collaborative simulation standards and NASA-STD-7009 compliance requirements.

1.2 SCOPE

This plan applies across all phases of the NASA program life cycle, including design, test, verification and evaluation (DDT&E), operations, and closeout. It is assumed that each Gateway Element will have a M&S Plan that details its internal processes and products, some of which may already be consistent with NASA-STD-7009 and others which may not be.

The Gateway program defines *cross-program M&S* as models and simulation, including supporting data and evidence, having some bearing across Gateway project boundaries and Gateway L2 offices as well as across ESD program boundaries. This

document addresses only *cross-program* M&S activities and levees expectations on how the credibility of models and simulations will be assessed and reported when used at the programmatic level. Additional description of cross-program model exchange processes is found in section 4.3 Gateway M&S Integration.

1.3 CHANGE AUTHORITY/RESPONSIBILITY

The NASA Office of Primary Responsibility (OPR) identified for this document is the Gateway Vehicle Integration Office. Proposed changes to this document shall be submitted via a Change Request (CR) to the Gateway Vehicle Integration Control Board for disposition. All such requests will adhere to Gateway Configuration Management Change Process defined in the Gateway Configuration and Data Management Plan, DSG-PLAN-004.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. In the event of conflict between the text of this document and the references cited, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless specific exemption has been obtained.

TABLE 2.1-1: APPLICABLE DOCUMENTS

Document Number	Document Revision	Document Title
NASA-STD-7009	A	Standard for Models and Simulations
NPR 7150.2	Current	NASA Software Engineering Requirements
IEEE 1516-2010	Current	Standard for Modeling and Simulation High Level Architecture (HLA)
FMI Specification	2.0	Functional Mock-up Interface for Model Exchange and Co-Simulation
SISO-STD-XX-20XX	0.3D	Simulation Interoperability Standards Organization (SISO) Space Reference Federation Object Model (FOM)

2.2 REFERENCE DOCUMENTS

Reference documents have information that is related to the content of this document or further inform related topics but do not drive implementation.

TABLE 2.2-1: REFERENCE DOCUMENTS

Document Number	Document Revision	Document Title
DSG-PLAN-001	Draft	Gateway Program Plan
DSG-PLAN-004	Draft	Gateway Configuration and Data Management Plan
GP-10022	Draft	Gateway Safety & Mission Assurance Plan
DSG-PLAN-007	Draft	Gateway Systems Engineering Management Plan
GP-10039	Draft	Gateway Verification and Validation Plan
GP-TBD		Gateway Integrated Analysis Plan
ESD 10044	Current	Cross Program Modeling and Simulation Plan

3.0 APPLICABILITY

This plan is applicable to all Gateway M&S and supporting data/information having some bearing across program and Gateway project boundaries. This includes (1) analytical models and simulations transferred from the author/owner to other elements or level 2 organizations, (2) shared data or analytical results used as model inputs by receiving organizations, and (3) M&S metadata and supporting information required for proper utilization by receiving organizations to support critical decision processes.

3.1 RELATIONSHIP TO NASA-STD-7009, STANDARD FOR MODELS AND SIMULATIONS

NASA-STD-7009 establishes uniform practices for modeling and simulation and provides an approved set of requirements, recommendations, and criteria with which M&S may be developed, accepted, and used. For L3 developed M&S, responsibility for compliance with NASA-STD-7009 remains with each Gateway element individually. For L2 developed M&S, L2 is responsible for compliance with NASA-STD-7009. This document is intended to support each element in achieving that objective where there is some reliance on cross-program modeling and simulation by:

1. Establishing criteria to designate M&S as “cross-program”.
2. Setting criteria and processes for determining criticality of cross-program M&S.
3. Establishing a standard set of supporting technical information for all critical cross-program M&S to enable credibility assessment of cross-program M&S.
4. Describing necessary partner involvement in achieving NASA-STD-7009 compliance when critical cross-program M&S are involved.
5. Establishing a cross-program M&S approach to ensure cross-program M&S integration, approval and delivery in advance of any authoritative action by the Gateway Vehicle Integration Control Board and release under Configuration Management (CM) access controls.

The criticality specific tailoring of NASA-STD-7009 for the Gateway program is detailed in Appendix D of this plan and provides a graduated application of the NASA-STD-7009 requirements based on criticality assessment results. For M&S assessed as high criticality the full complement of requirements apply while for lesser criticality M&S a tailored set are applied.

For some NASA-STD-7009 requirements, Gateway program specific roles and responsibilities and/or levels of delegation are specified. In these cases, Gateway specific implementations of the NASA-STD-7009 requirements are indicated with a [7009 M&S #] notation and are detailed with a *will* (rather than a *shall*) as the /nasa-STD-7009 requirement is invoked via the tailoring in Appendix D.

3.2 RELATIONSHIP TO NPR 7150.2 NASA SOFTWARE ENGINEERING REQUIREMENTS

NPR 7150.2 is applicable for all Gateway software, of which M&S software is a subset. Typically, M&S software is classified as Class D or E and is designated as non-safety critical. Usage scenarios may arise that drive a higher classification and/or safety critical rating, such as analysis results that are used as a hazard mitigation. Responsibility for compliance with NPR 7150.2 remains with each Gateway element individually.

4.0 GATEWAY M&S OVERVIEW

The Space Policy Directive 1 is to:

“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations.”

In order to accomplish the objectives detailed in this directive, the Gateway assembly will provide a platform to conduct a meaningful series of capability demonstrations to enable future exploration efforts beyond Earth’s sphere of influence. To achieve this, the Gateway program will design, develop, build, launch and operate a spacecraft comprised of many distinct elements which will be launched independently and then assembled in lunar orbit. These Gateway Elements will be acquired from a number of different sources, including both domestic and international partners.

To ensure integrated functionality of the Gateway, M&S will be applied through the entire program life cycle and will be provided by a variety of sources including domestic and international partners. Cross-program M&S capability and level of rigor will evolve as the program activities mature through the life cycle. The following section describes this graduated approach to M&S capability development and describes types of assessments addressed by M&S as the program matures.

4.1 INCREMENTAL FUNCTIONALITY

Assessments, the process through which decisions are made, are conducted throughout the program life cycle. M&S are a part of how program decisions are made. This document addresses the M&S portion of assessments.

Modeling and simulation capabilities evolve through the Gateway program life cycle to support the design, test, verification, training and operation life cycle phases. These phases are supported by distinct, yet iterative, types of assessments, all of which are supported by M&S capabilities:

- Systems Engineering
- Analysis and Design
- Hardware-/Software-in-the-Loop Assessment
- Operator-in-the-Loop Assessment
- In-Service Operations Assessment

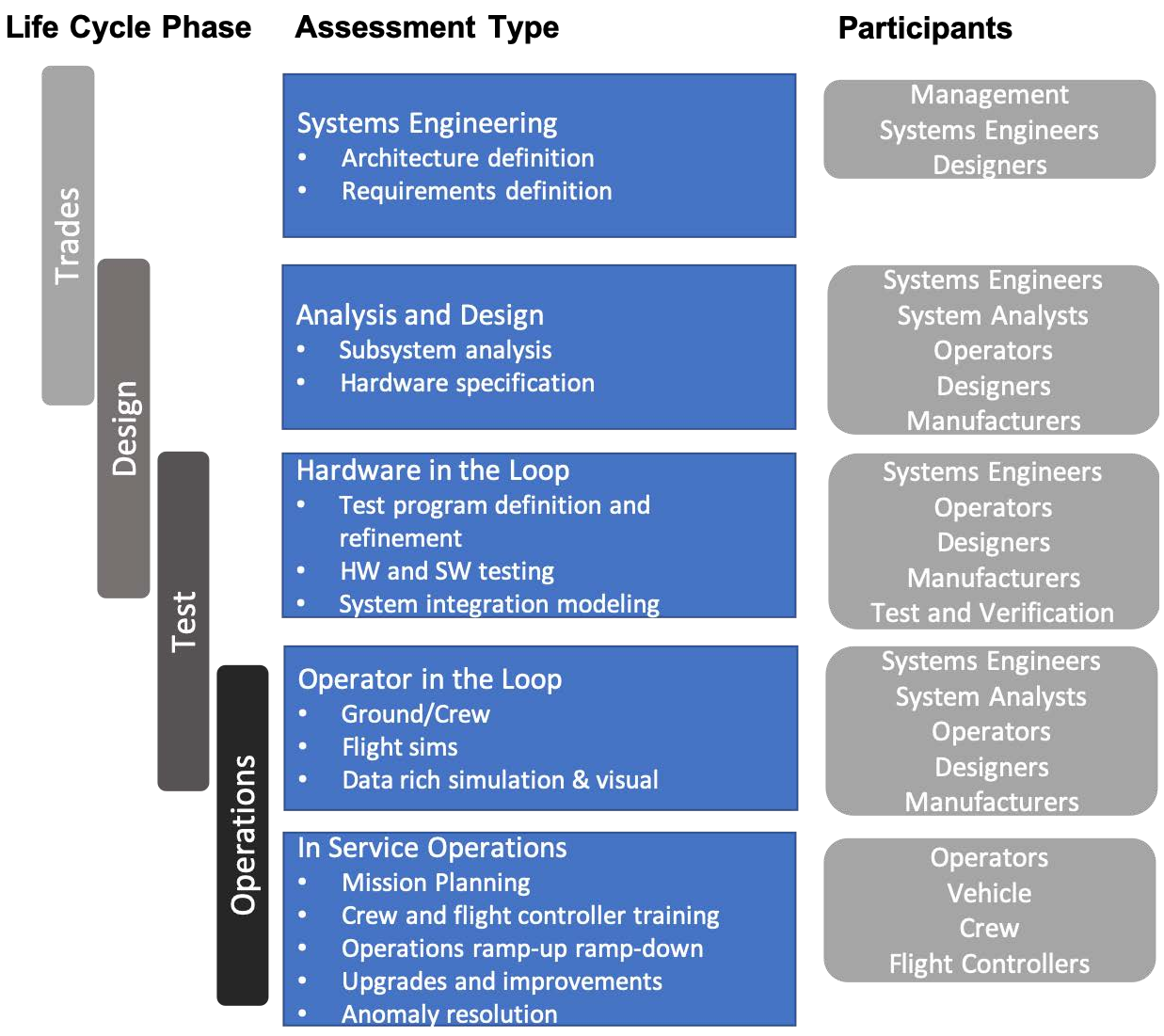

FIGURE 4.1-1. M&S SUPPORTED LIFE CYCLE ASSESSMENT

4.2 TYPES OF MODELS AND SIMULATIONS

The following describes the type of models and simulations that will be developed and used for each type of assessment.

4.2.1 Systems Engineering Assessments

The requirements and early conceptual formulation phase of a system is supported, initially, by systems engineering assessments. This involves conducting trades that result in the architecture definition, the development of system requirements, requirements traceability, development of ground rules and assumptions and the development of Figures of Merit. This is typically supported with decision analysis models and simple spreadsheet-based concept models.

4.2.2 Analysis and Design Assessments

Analysis and Design assessments span the conceptual and preliminary design phases. These assessments typically use non-real-time, event-driven models that support subsystem analysis and hardware specification. These models are built upon historical

and physics-based relationships and algorithms. Note that these assessments do not end with the conceptual engineering phase. Instead, they include preliminary and detailed engineering assessments that occur later in the architecture or system development phases. The subsequent analysis and design assessments involve the use of more detailed tools, involving greater fidelity and more discipline-focused analyses. These models typically are the responsibility of the project engineering teams.

4.2.3 Hardware/Software-in-the-Loop Assessments

The intent of these analyses is to replace the developed models and simulations with actual flight and ground system hardware and software, providing a more realistic assessment of the systems. The functionality provided by these assessments supports Flight Test program definition and refinement, a robust and realistic ground integration test program, a continuously improving high-fidelity baseline for analyzing new concepts over the life cycle of the program, and an increasingly high-fidelity baseline for analyzing in-flight anomalies

4.2.4 Operator-in-the-Loop Assessments

Operator-in-the-Loop assessments will include capabilities for incorporating the operators (i.e., ground, flight and crew) into the analysis and design of the systems early in the life cycle. Specifically, this involves developing real-time simulation capabilities that allow for a very early representation and exercising of the operational functions permitting a “see, exercise and modify” capability for the operators. Also provided during this phase are data-rich simulation and visualization capabilities. In these types of simulations results depend on the actions of the operators interacting with simulated environments.

4.2.5 In-Service Operations Assessments

The In-Service Operations assessments will provide support of the systems that are operational. These will support mission planning activities, crew and flight controller training, operations ramp-up/down, upgrades and improvements to the system and anomaly resolution. The facilities and simulations developed over the life cycle of the program form the basis for this capability. Enabling these assessments will be two adjunct areas that will support the use and operation of models and simulations. First is a data management architecture and its associated processes that allow consistent cataloging and use of appropriate data. Second are efforts to enhance presentation and visualization of simulation results.

4.3 GATEWAY M&S INTEGRATION

The Gateway M&S Plan provides a centralized approach to the management, guidance and execution of cross-program M&S exchange. While each Gateway M&S element will follow its own processes to achieve within-element M&S needs, cross-program M&S activities will follow the processes defined in this plan.

Figure 4.3-1 shows exchange of cross-program M&S following the centralized, cross-program processes, while each element or program follows its own M&S processes for M&S needs internal to their organizations.

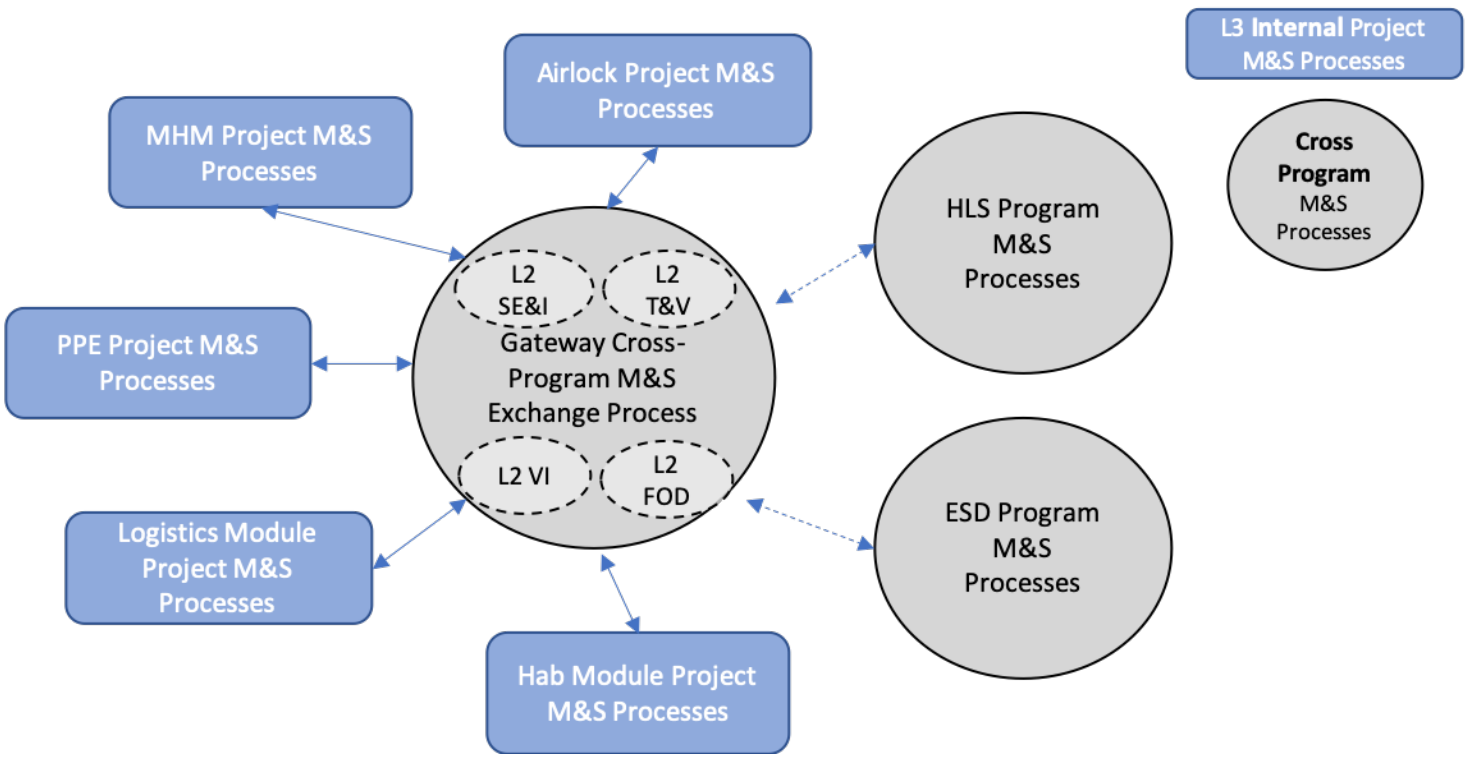

FIGURE 4.3-1. CROSS-PROGRAM M&S EXCHANGE

To realize the considerable benefit and opportunity for M&S integration and re-use and to enable a more robust and accurate representation of the system at each level, Gateway M&S will facilitate horizontal and vertical collaboration between the communities by:

1. Providing M&S requirements compliance assurance,
2. Providing processes and infrastructure to handle the management of cross-program M&S,
3. Defining interoperability standards and detailing approaches based on system coupling, and
4. Supporting and performing the development and integration necessary to support integrated analysis activities

5.0 IMPLEMENTATION

5.1 ORGANIZATION

The Gateway M&S System Manager role resides in the Vehicle Integration (VI) organization within the Gateway Program. From within the VI team the M&S SM will facilitate M&S exchange and integration to support emulation needs across the elements as well as to build the L2 integrated Gateway stack simulation to satisfy performance analysis, integrated V&V, training and operational needs.

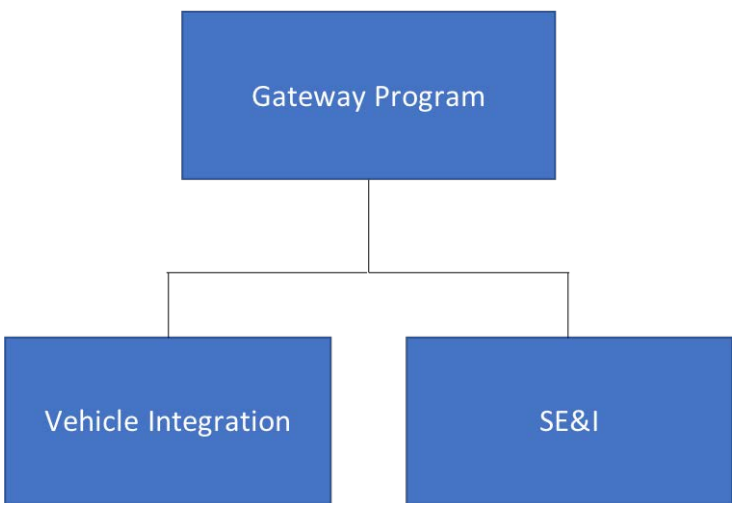

FIGURE 5.1-1. GATEWAY PROGRAM ORGANIZATION

5.2 ESD RELATIONSHIP

The Gateway program and the ESD program are peer organizations which require integration. The Gateway program will leverage existing communication channels where possible and engage with ESD through the Gateway Systems Engineering and Integration (SE&I) organization where the CPIT structure integrates across ESD and Gateway.

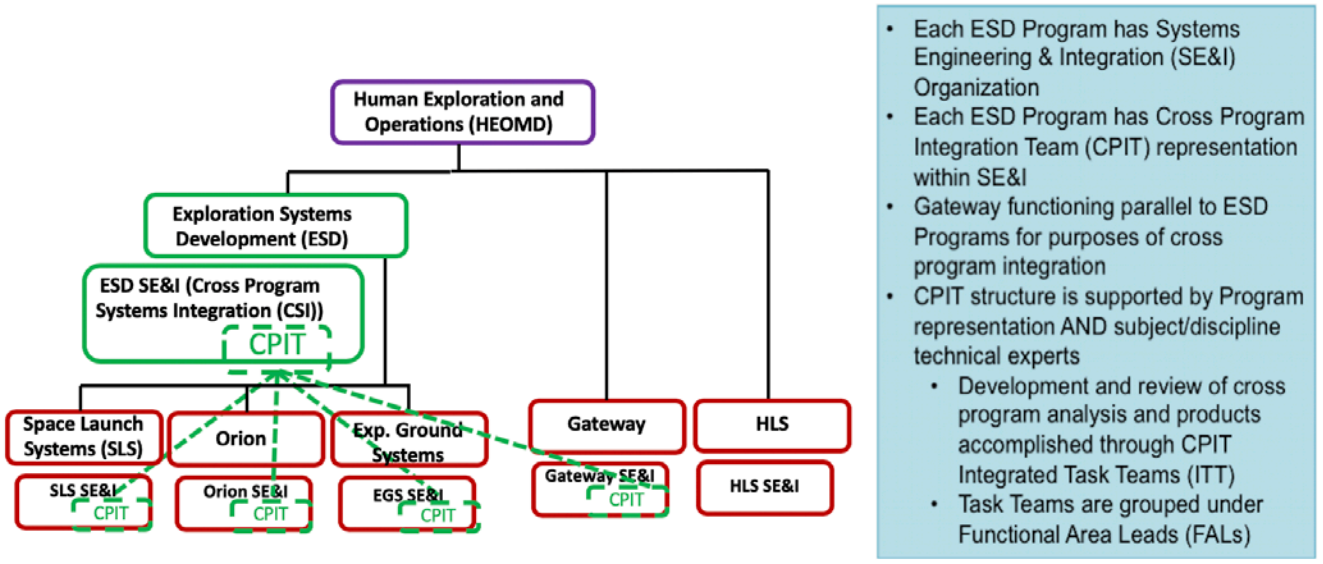

FIGURE 5.2-1. ESD - GATEWAY CROSS-PROGRAM ENGAGEMENT

5.3 ROLES AND RESPONSIBILITIES

To enable efficient M&S exchange across elements, it is critical to define roles and responsibilities for all participants and stakeholders. Descriptions provided below include specific roles called out in NASA-STD-7009 and include Gateway specific M&S roles. NASA-STD-7009 section 4.1 indicates several important roles including, program management and technical authority. The Gateway Program Manager and Technical Authority delegate some responsibilities to the M&S System Manager, the M&S Developers and the M&S Analysts while maintaining insight and providing guidance for M&S activities.

Role	Responsibilities
Program Management (PM) The Gateway Program Management may delegate their authority to element managers, subsystem leads or to an individual overseeing analysis activity.	- *[**GMS 1**] The PM shall make delegates aware of full responsibilities listed below to ensure compliance.* *Rationale: Delegation to the lowest level possible while achieving requirements is optimal but successful delegation is grounded in the assumption that delegates understand all expectations and responsibilities.* PM in conjunction with the TA: - *[**7009 Section 4**] PM will identify and document the parties responsible for complying with NASA-STD-7009 requirements* *Rationale: The Gateway PM will identify the appropriate person to fill the role of "responsible party" to best serve the requirement intent with the goal of delegating responsibility to the person with the best knowledge and authority to implement the requirement.* - *[**7009 Section 4.1**] PM will identify and document critical decisions to be addressed by M&S* *Rationale: Identification of critical decisions to be addressed with M&S allows for proper planning to ensure critical M&S have been developed and used in a manner that provides artifacts necessary for credibility and suitability for use assessments.*
Program Technical Authority (TA)	- ***[GMS 2]** The TA shall make delegates aware of full responsibilities listed below to ensure compliance.*

The Gateway Technical Authority may delegate their authority to element TAs, subsystem leads or to an individual overseeing analysis activity.	*Rationale: Delegation to the lowest level possible while achieving requirements is optimal. Successful delegation is grounded in the assumption that delegates understand all expectations and responsibilities.* - *[**7009-M&S 2**] TA will authorize any tailoring to NASA-STD-7009.* *Rationale: Documenting appropriate scope, including tailoring, provides clarity and, where appropriate, relief from requirements.* - *[**7009-M&S 3,4**] TA will specify applicable versions of applicable documents.* *Rationale: Consistent and current document references keep efforts within the program from diverging.* - *[**7009-M&S 5**] TA will resolve conflicts between NASA-STD-7009 and other requirement documents.* *Rationale: Clarification of full requirement set needed to support development, use and tailoring.* - *[**7009-M&S 8**] TA will define objectives and requirements for M&S products including: (1) acceptance criteria including any endorsement for the M&S and (2) intended use, metrics, Verification, Validation and Uncertainty characterization, reporting of M&S information for critical decisions and CM of M&S.* *Rationale: Early definition and communication of objectives and requirements informs developers and users and allows for proper planning of required M&S activities.*
Gateway M&S System Manager (SM)	- *[**GMS 3**] The M&S SM shall ensure cross-program M&S processes and products support stakeholder needs and communicate cross-program M&S progress, issues and risks to program management.* *Rationale: To support cross-program M&S exchange, stakeholder needs must be understood. Informing program management of issues, risks and progress allows for adjustment to program plans as needed.* - *[**GMS 4**] M&S SM shall ensure NASA-STD-7009 compliance as appropriate based on M&S criticality and life cycle phase.* *Rationale: As cross-program M&S are exchanged, requirements compliance needs to be understood and documented to clarify expectations and allow for adequate planning. If gaps are discovered, they are documented so that all parties understand the pedigree of the M&S.* - *[**GMS 5**] M&S SM shall stand up a Modeling and Simulation Working Group to review criticality assessments, determine which models and simulations should be shared between elements, oversee creation of the Modeling and Simulation Database, and verify that the database is properly populated and maintained.* *Rationale: Coordination of cross-program M&S stakeholder needs including identifying cross-program M&S and reviewing criticality assessments ensures M&S activities are not duplicated, promotes leveraging existing capabilities and provides guidance through the criticality assessment process.* - *[**GMS 6**] M&S SM shall serve as the signature authority on proposed waivers to requirements contained in this plan.* *Rationale: Waiver approval authority resides with the PM and TA (delegated to the M&S SM). As cross-program M&S are developed there may be instances where an M&S does not currently or cannot meet the Gateway M&S Plan requirements. In these cases, a waiver must be requested by the M&S owner with adequate rationale and description of related risk. The M&S SM will evaluate the waiver and, if approved, release the requester from meeting the requirement.*
M&S Developers	- *[**7009-M&S 10-21**] M&S Developers will implement NASA-STD-7009 requirements for cross-program M&S related to development, verification, validation and uncertainty characterization in development.* *Rationale: To support assessment for intended use, development must be performed with required artifact and evidence generation in scope to provide the information required for credibility assessment.*

M&S Analysts	- *[**7009-M&S 22-39**] M&S Analysts will implement NASA-STD-7009 requirements for cross-program M&S related to use, uncertainty characteristics in use, sensitivity analysis, credibility assessment and reporting.* *Rationale: To draw conclusions and provide recommendations based on cross-program M&S results the analyst will need to provide all applicable information in support of credibility assessment for intended use.*
Domain Expert (DE)	- *[**GMS 7**] The M&S DE shall provide input to program management and the TA to assess the influence an M&S has on critical decisions.* *Rationale: Criticality determination resides with the PM and TA who specify the consequence. Assessing the influence of an M&S on a decision is well served by domain expertise.*
M&S Working Group	- *[**GMS 8**] The M&S Working group shall serve as the forum to coordinate stakeholder needs, provide guidance for cross-program M&S processes and requirement implementation, identify cross-program M&S dependencies and track cross-program M&S progress.* *Rationale: Successful model exchange is enabled through vetting of stakeholder needs, execution of a common set of process and understanding cross-program dependencies. The working group is chartered with technical, schedule and budget decision making capability as delegated by the Gateway Vehicle Control Board (GVCB)*

5.4 PROCESSES

This section provides a description of the Gateway cross-program M&S process where *cross-program is defined* as models and simulation, including supporting data and evidence, having some bearing across Gateway project boundaries. These processes are established to provide program decision makers with full insight into pedigree and credibility of cross-program M&S. Figure 5.4-1 details cross-program M&S activities through the full life cycle from M&S identification through use in program decisions. This process is repeated for each program level Integrated Analysis Cycle (IAC) and Verification Analysis Cycle (VAC). Descriptions of key process areas are provided in the following sections.

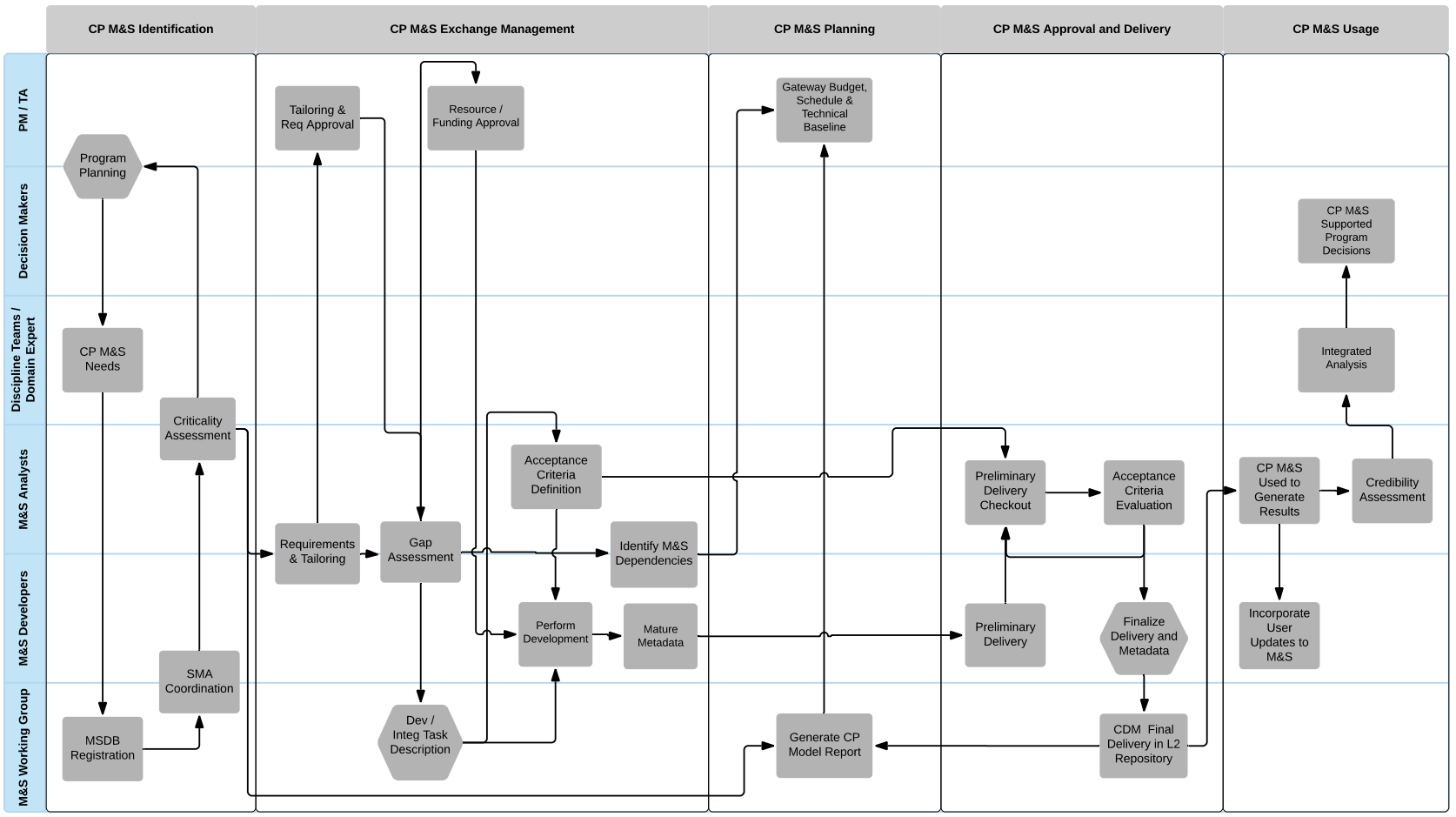

FIGURE 5.4-1. CROSS-PROGRAM M&S PROCESS FLOW

5.4.1 Identification of Cross-Program M&S

The Gateway program defines *cross-program M&S* as models and simulation, including supporting data and evidence, having some bearing across Gateway project boundaries.

As a part of program planning for IAC, VAC, and training and operations activities, the reference design and requirements for the current cycle define the analyses to be performed. Of the defined analyses, those that anticipate utilizing cross-program M&S for vehicle performance and functionality assessments will be noted in their task descriptions.

The M&S Working Group (MSWG), with participation from all stakeholders including the Element projects, L2 SE&I, L2 V&V, SMA, Human Lander System (HLS) and ESD-Orion, will review task descriptions where cross-program M&S are

required to fulfill integrated design, test, verification, training and operational objectives and register the cross-program M&S in the Model and Sim Database (MSDB).

Once a cross-program M&S need is identified, developers, analysts, and DEs will be designated for the activity.

> *[**GMS 9**] The developer and analyst in cooperation with the M&S SM shall analyze the identified M&S need against existing and planned M&S capabilities, map capabilities to needs, identify dependencies and gaps in capability, and ensure efforts are not duplicated across the program.*
>
> *Rationale: The functional capabilities of existing and planned M&S as well as the rigor applied during development and previous use activities may be different from the identified need.*
>
> *[**GMS 10**] The analyst shall assess identified M&S capabilities and proposed development to close any capability gaps and evaluate appropriateness for proposed use.*
>
> *Rationale: Current M&S state and any proposed modifications to meet proposed use need to be evaluated so that resources are applied appropriately to meet analysts' needs.*
>
> *[**7009-M&S 7**] Domain Experts in coordination with the M&S SM will identify and document if M&S is in scope of the NASA-STD-7009.*
>
> *Rationale: Identifying if M&S is in scope provides clarity to developers, users and analysts and allows for better M&S planning to accommodate requirements. In-scope determination resides with the PM (delegated to the domain experts). Any reclama will be resolved by the program Technical Authority.*

5.4.2 Criticality Assessment

NASA-STD-7009 section 4.1 indicates that the responsibility for the identification of critical decisions resides with program management and the technical authority. Because of the volume and breadth of possible decisions dependent on M&S, the Gateway Program Manager and Technical Authority will delegate the assessment of criticality to a team consisting of domain experts and M&S experts in the relevant disciplines, with guidance on and tracking of the assessment process provided by the M&S System Manager. Any assessments that result in the identification of high criticality decisions will be reported to the program management and TA.

Developers in cooperation with SMA, will focus on likelihood of M&S use in final flight vehicle HW/SW certification, V&V hazard controls and operational decision making to inform acquisition processes and planning efforts and avoid missing any data delivered to support certification V&V and operational decision-making use.

> *[**GMS 11**] The developer and M&S SM in cooperation with SMA shall consider the M&S "final use" early in the life cycle.*
>
> *Rationale: Early consideration of "final use" allows for proper planning for NASA-STD-7009 and NPR 7150.2 compliance.*

As outlined in NASA-STD-7009 Appendix D, M&S Criticality Assessment, the determination of a model's criticality should be based upon an assessment of the consequences of a decision and the influence of the M&S on that decision. The Gateway M&S criticality assessment considers (1) the consequences to safety or mission success criteria if a decision proves incorrect, (2) the immediacy of the consequence if a decision proves incorrect, and (3) the degree to which the M&S results influence that decision.

> *[**GMS 12**] The Domain Experts, M&S Users, and M&S SM shall use the criticality assessment method described in in NASA-STD-7009 Appendix D with additional consideration for (1) the immediacy of consequence mentioned above and (2) potential future use of the model. [NASA-STD-7009 M&S 6]*

Rationale: Criticality determination resides with the PM (delegated to the M&S SM) and TA who specify the consequence. Assessing the influence of an M&S on a decision is well served by domain expertise. The immediacy of consequence should be considered when evaluating criticality. If the decision consequence is not immediate, consideration should be given to reducing the assessed criticality unless no further analysis is planned related to the decision. Conversely, if low criticality M&S is expected to be used for higher criticality decisions at a future point in the project, consideration should be given to initially designating it as medium criticality. In either case, the life cycle development plan for the model should consider its future use.

*[**GMS 13**] The M&S System manager shall mark all critical cross-program M&S in the MSDB.*

Rationale: Easy identification of critical M&S allows for clear insight to dependencies. All organizations using critical cross-program M&S need insight to effectively plan, identify risks and monitor progress.

*[**GMS 14**] The Gateway program and L3 projects shall apply the tailoring in Appendix D of this document as the Gateway specific implementation of NASA-STD-7009.*

Rationale: To provide a graduated approach to NASA-STD-7009 compliance based on criticality assessment results. For M&S assessed as high criticality the full complement of requirements apply while for lesser criticality M&S a tailored set are applied.

The NASA-STD-7009, Appendix A criticality matrix is shown in table 5.2.3-1 and the associated Gateway Program tailoring is shown in Appendix D of this document. Areas marked in green reflect low criticality decisions and require little evidence of NASA-STD-7009 compliance. Areas marked in red reflect high criticality decisions and require complete compliance. Areas marked in yellow reflect medium criticality decisions and require an intermediate level of compliance that is dependent on the nature of the decision and will be defined by the M&S Working Group.

M&S Results Influence	I: Negligible	II: Minor	III: Moderate	IV: Significant	V: Catastrophic
5: Controlling	(G)	(Y)	(R)	(R)	(R)
4: Significant	(G)	(Y)	(Y)	(R)	(R)
3: Moderate	(G)	(Y)	(Y)	(Y)	(R)
2: Minor	(G)	(G)	(G)	(Y)	(Y)
1: Negligible	(G)	(G)	(G)	(G)	(Y)
	Decision Consequence				

FIGURE 5.4-2. M&S CRITICALITY ASSESSMENT MATRIX

Details on how the Gateway program will interpret and implement the *decision consequence* and *M&S influence factors* are outlined in Tables 5.2.3-2 and 5.2.3-3.

Consequence Level	Vehicle Damage or Personal Injury	Schedule Impacts	Cost Impacts to Program	Mission Success Criteria Impacts
Negligible	No adjustments or treatment required	None	None	None

Minor	Minor adjustments / first aid	Acceptable delays with minor schedule impacts	Impacts within mgmt. reserve	Impact to secondary mission objectives
Moderate	Minor repairs / emergency care	Delays with moderate schedule impact, partial mitigation possible with accepted schedule risk	Cost impacts acceptable	Loss of primary mission objectives
Significant	Major repairs / severe injuries	Significant delays with major schedule impacts	Major resource reallocations	Potential failure to accomplish mission objectives
Catastrophic	Complete loss of vehicle / death or disabling injuries	Delays which could cause project scope to change significantly or risk cancellation	Cost overruns which could result in cancellation	Failure to accomplish major mission objectives

TABLE 5.2.3-2 M&S DESIGN DECISION CONSEQUENCE LEVELS

Influence Level	Mission Success Criteria Impacts
Negligible	Design decision is primarily based on test results or prior operational experience. The use of the subject M&S is only used to understand minor elements associated with the decision.
Minor	Significant test or prior operational experience baseline the analyses associated with the decision. The subject M&S is primarily used to integrate these factors.
Moderate	Much of the decision process is based on the M&S product under review, but there are several other M&S products, test or prior operational experience used in significant aspects of the decision.
Significant	Critical portions of the design decision are based on the M&S product under review with only minor support from other M&S, testing or experience.
Controlling	The design decision is solely based on the results generated by the M&S product under review.

TABLE 5.2.3-3 M&S INFLUENCE LEVELS

Criticality assessment discrepancies should be resolved at the M&S Working Group. If assessment discrepancies are not able to be resolved at the M&S Working Group, they will be elevated to the Gateway SE&I Control board or the Joint Integration Control Board (JICB) as required.

5.4.3 Requirement Specification and Tailoring

For M&S developed to address high criticality decisions, the designees defined in this plan - the M&S developer and the M&S analyst - will fully address all 7009 requirements.

For M&S being developed to address medium criticality decisions, a specific proposed tailoring of the 7009 requirements will be performed by the designees. The designees will obtain approval for the proposed tailoring from the M&S SM and the program element who assigned the action to develop the M&S.

> *[**7009-M&S 8**] The analyst in coordination with the developer will specify requirements for verification, validation and uncertainty characterization for the intended M&S use.*
>
> *Rationale: To support analyst M&S needs, the level of verification, validation and uncertainty characterization required may vary through the life cycle. Defining what is required per iteration allows for a graduated approach to development and compliance. Additionally, if "final use" has changed since its initial definition, the requirements should be re-evaluated.*
>
> *[**7009-M&S 8**] For each cross-program M&S use the analyst will define and document acceptance criteria for the M&S.*
>
> *Rationale: This acceptance criteria will be used to evaluate the M&S delivery.*
>
> *[**7009-M&S 5**] The analyst in coordination with the developer will tailor the NASA-STD-7009 requirements per guidance provided in Appendix D of this plan. The analyst will provide the proposed tailoring to the M&S SM, program management and TA for approval.*
>
> *Rationale: The Gateway M&S Plan provides a criticality based tailoring option for cross-program M&S. The analyst with input from the developer should apply the NASA-STD-7009*

requirements appropriate for the M&S based on the criticality assessment results. For M&S addressing low criticality decisions, much of the standard is not required. For high criticality cases, the full set of 7009 requirements should be addressed. For medium criticality decisions, coarse tailoring should be considered by including or waiving entire sections en-masse (e.g., General M&S Development, Verification, Validation, Uncertainty Characterization in Development, M&S Use, Uncertainty Characterization in Use, Sensitivity Analysis, Credibility Assessment, Results Reporting) as makes sense per the analysis being performed.

Once approved the tailoring will be added to the M&S delivery package as a part of the Gateway M&S requirement documentation.

5.4.4 M&S Exchange Management

This section details the processes used to manage the cataloging, access, approval and delivery of cross-program M&S. The intent is to provide a single process to handle all cross-program M&S regardless of criticality or type. The types and amount of metadata and supporting documentation required will differ depending on (1) criticality assessment results and (2) software classification and safety criticality designation. The metadata requirements are available in Appendix C of this plan and include an incremental approach to NASA-STD-7009 compliance through the program life cycle.

Cross-program M&S exchange can be executed in multiple forms via (1) analytical models transferred from the author/owner to other elements or Level 2 organizations, (2) shared data or analytical results used as model inputs by receiving organizations and (3) M&S metadata and supporting information required for proper utilization by receiving organization(s) to support critical decision processes. The Gateway M&S organization will prefer the maximum transparency in M&S exchange as possible. Because instances will exist where proprietary and/or export control concerns are not able to be mitigated by applied security measures, in those cases deliveries may be limited to binary deliveries or data only deliveries.

5.4.4.1 Cross-Program M&S Cataloging

*[**GMS 15**] The M&S SM shall register all M&S identified as cross-program in the MSDB. An MSDB identifier shall be assigned and the registration metadata shall be completed.*

Rationale: Cataloging of all M&S used for cross-program activities allows for centralized exchange and insight into available capabilities, dependencies and compliance status.

Cross-program M&S packages are incrementally completed and updated throughout the product's life cycle according to the priorities and requirements for each use. The maturing of their related metadata and supporting documentation will follow as a part of planned M&S maturity. Full details on registration, programmatic and compliance metadata and related maturity expectations per life cycle phase are provided in Metadata, Appendix C of this plan.

5.4.5 Metadata

This section defines the metadata required for cross-program M&S. Further details about the metadata items can be found in Appendix C.

5.4.5.1 Registration Metadata

The required registration metadata for initial incorporation into the MSDB and a listing of responsible party for each is found in the table below.

Metadata ID	Description	Responsible Party
Model Name	Name of cross-program M&S	Developer
MSDB Unique Identifier	ID assigned when entered in MSDB	M&S SM
Version/Revision	Version of M&S being released for use	Developer
Metadata Revision	Version of metadata update	Developer
Release Date	Current date for release for use	Developer
Classification	7150.2 Classification (if software)	Developer
Intended Use	Intended/Proposed use(s) for M&S	Analyst
Element Subsystem	Name of subsystem modeled	Developer
Life Cycle activity	Current life cycle activity the M&S is supporting	Analyst
Model Point of Contact	Identified person for questions and information about M&S	Developer

TABLE 5.3.4.1-1 REGISTRATION METADATA

5.4.5.2 Programmatic Metadata

Programmatic metadata includes information detailing program to program agreements on schedule, documentation of dependencies and any exchange of resources to accomplish the cross-program M&S activities in the MSDB. These details will be coordinated and agreed to in the M&S Working Group.

*[**GMS 16**] The M&S SM shall complete the programmatic metadata in the MSDB.*

Rationale: Capture of program agreements and dependencies allows for planning and tracking throughout the program life cycle.

5.4.5.3 Collaborative Simulation Metadata

This metadata includes information required to support exchange and collaborative simulations activities, and is specified in Appendix C.

*[**GMS 17**] The M&S SM shall complete the collaborative simulation metadata in the MSDB.*

Rationale: To successfully exchange M&S to be used collaboratively to satisfy programmatic needs these details must be documented for participants.

5.4.5.4 NASA-STD-7009 Compliance Metadata

All data required for NASA-STD-7009 compliance will be captured in MSDB metadata. In many instances the metadata field will be populated with a reference to supporting documentation found in the cross-program M&S delivery package.

*[**7009-M&S 10-39**] The analyst, in coordination with the developer, will ensure that all applicable NASA-STD-7009 requirements have been met, documented and the relevant metadata is complete in the MSDB.*

Rationale: To support credibility assessment and to provide program decision makers with full insight, appropriate artifacts and evidence must be provided to using organizations.

As M&S capability is incrementally provided to support assessments for each life cycle phase, a graduated approach to NASA-STD-7009 compliance will be applied. The final use of each model or simulation product will be considered, and targets set on each credibility factor for the intended use of product.

*[**GMS 18**] The M&S SM shall consider final use and apply the NASA-STD-7009 requirements as prescribed in Metadata, Appendix C of this plan to allow for incremental requirements compliance.*

Rationale: Incremental compliance is supported through a graduated approach through the life cycle. The Metadata detailed in Appendix C includes the information, supporting documentation and evidence required for compliance per life cycle phase (Trades, Design, Test, Operations).

*[**GMS 19**] The M&S WG shall establish target credibility factor expectations [NASA-STD-7009, Appendix E, Table 3] for each development stage of medium and high criticality models.*

Rationale: cross-program M&S user requirements will evolve through the program life cycle. To support accurate M&S planning to meet user needs the M&S WG will determine appropriate targets (numeric scores) for credibility factors based on life cycle phase and intended use.

5.4.5.5 NPR 7150.2 Supporting Metadata

The Gateway M&S System Manager will work with the program manager or their delegate to assess software safety criticality and classify cross-program M&S products with the understanding that the software assurance organization will perform an independent classification assessment as required. [NPR-7150.2 SWE-020, SWE-132, SWE-133]

Rationale: Software classification and safety criticality rating affect the level or rigor, artifacts and evidence required during M&S development and use. The classification should happen as early in the life cycle as possible to allow for proper planning. In most cases as soon as M&S final use is understood, classification should be assessed.

*[**GMS 20**] The M&S SM shall capture 7150.2 classification and safety criticality rating information in MSDB metadata.*

Rationale: Software classification and safety criticality rating, as defined in NASA-STD-7150.2, are key elements to criticality assessments.

5.4.5.6 Cross-Program M&S Planning

Cross-program M&S programmatic information is reported to program management to inform planning activities and to provide insight into critical and integrated M&S activities so that when program cost, schedule or technical baselines change, stakeholders' needs are addressed.

*[**GMS 21**] The Gateway M&S SM shall report all critical cross-program M&S to program management and identify and communicate cross-program M&S dependencies to ensure that they are incorporated into program baseline planning activities.*

Rationale: To provide required M&S capabilities M&S development, verification and validation requirements must be understood and accounted for in program planning activities. Cross-program M&S dependencies must be understood during planning activities to ensure stakeholder needs are met.

5.4.5.7 M&S Package Approval and Delivery

When the M&S is ready for delivery for use, it is recommended that the developer prepare a preliminary/informal delivery in advance of finalization and formal delivery. This allows the using organization to confirm they have full access to all models, data, supporting documentation and evidence as well as complete metadata. After the using organization evaluates the delivery against the acceptance criteria, confirms the product is complete (including running baseline/regression test cases) a formal delivery can be prepared.

*[**7009-M&S 9**] The developer will prepare the formal delivery and perform a final check for (1) deliverable completeness (including tests and baseline/regression results) to confirm proper functionality, (2) complete metadata at a maturity level to support appropriate compliance as described in Appendix D and (3) supporting documentation and evidence required for compliance including any technical reviews associated with the package.*

Rationale: Formal delivery to be incorporated into L2 repository will be a snapshot version of the deliverable and must be "stand alone" so that users may receive the delivery and have everything needed to use the M&S per defined acceptance criteria.

*[**7009-M&S 23,32**] The analyst will confirm the final delivery package meets the acceptance criteria, including running provided test cases, and will ensure it is appropriate for intended use.*

Rationale: Checking the delivery against acceptance criteria confirms M&S will be suitable for use. Assessment of appropriateness for use resides with the TA (delegated to the Analyst).

5.4.6 Intellectual Property (IP) Security

The Gateway Program is being developed together with International Partners and corporations. With these partnerships comes the need to provide IP security for cross-program M&S.

*[**GMS 22**] The M&S SM shall provide access control to the L2 MSDB and the L2 repository to strictly limit access to only mutually approved parties.*

Rationale: International Partners and corporations have export control and proprietary interests that must be accommodated to enable cross-program M&S exchange.

In cases where export control and/or proprietary interests cannot be accommodated such that centralized M&S exchange and storage is not feasible,

*[**GMS 23**] The Gateway M&S SM shall follow collaborating commercial and International Partner processes for exchange of data and shall ensure that data exchange compliance is achieved to enable collaborative simulation and data exchange.*

Rationale: When centralized M&S exchange and storage is not feasible, Gateway M&S SM will ensure the ability to perform collaborative simulation and data exchange.

5.4.7 Configuration and Data Management

Prior to delivery for cross-program use all Gateway M&S is under the control of its originating organization. All delivered, cross-program M&S are stored in the L2 repository. Metadata related to the delivery are stored in the MSDB and include a link to the L2 repository location where the M&S are stored.

*[**GMS 24**] The M&S System Manager shall store cross-program M&S deliveries in the L2 repository under Configuration and Data Management (CDM) control. It will be made available for release with access provided in a manner that adheres to the IP Security Management process described in the previous section.*

Rationale: Central storage and configuration management enables centralized M&S exchange.

*[**GMS 25**] L2 and Element organizations delivering M&S to the L2 repository shall configuration manage their M&S within originator organizations such that CM configuration specification provides all items necessary for a receiver to rebuild, execute, reproduce results and access all supporting documentation included in the delivery.*

Rationale – All M&S products, regardless of origination, are provided to ensure full product availability and function.

5.4.8 Stewardship

To fully realize the efficiency and productivity gains of model sharing and exchange, proper stewardship of received deliveries is necessary. The process to enable good stewardship of shared models is straightforward and best executed when incorporated into nominal workflow. Upon delivery from one organization to another there will often be cases where enhancements or modifications are made by the using organization and must be submitted to the originator. If submittals are needed more frequently than the delivery is expected to be updated in the MSDB, the appropriate submittal frequency will be captured as a part of the programmatic metadata to clarify expectations and allow for proper M&S release planning.

*[**GMS 26**] Using organizations shall submit all modifications, enhancements and fixes back to the developing organization for incorporation in future deliveries per the agreed upon frequency.*

Rationale: This feedback process benefits both the developing and using organizations. By frequently providing modifications back to the developer organization, the changes and improvements can be folded back into their product in an incremental manner and the using organization can expect smoother efforts to step up to more mature versions of the deliverable with their modifications included as part of the configuration managed package. This process prevents diverging products. If cases arise where proprietary data is inserted into a delivered model set, the vendor and receiver will come to an agreement on how to properly handle the data and manage redelivery.

5.4.9 M&S Credibility Assessment

As outlined in NASA-STD-7009 Appendix E, M&S Credibility Assessment, the determination of a model's credibility for intended use, should be based upon an assessment of several key factors which is enabled by implementing the NASA-STD-

7009 M&S requirements. The Gateway M&S credibility assessment considers the 8 key factors detailed in the standard, Data Pedigree, Verification, Validation, Input Pedigree, Uncertainty Characterization, Results Robustness, M&S History, and M&S Process/Product Management.

> *[**7009-M&S 31**] The analyst will perform a credibility assessment of results by following the credibility assessment approach defined in NASA-STD-7009 Appendix E.*
>
> *Rationale: Credibility assessments are performed to provide program decision makers with full insight into pedigree and suitability for intended use. Responsibility to assure that credibility assessment of results has been performed resides with the TA and is delegated to the analyst.*

To provide decision makers with the most complete understanding of the M&S qualities and usage, several key areas are explicitly reported with M&S results. These key areas are covered in Appendix C, Metadata, and will be reported to management when the technical results and recommendations are provided to decision makers.

> *[**7009-M&S 32-39**] When presenting M&S results to decision makers, the analyst will report on (1) description of the risks associated with accepting the results of the cross-program M&S, (2) the credibility of the results, (3) uncertainty in the results, (4) any caveats associated with the results, (5) the best estimate of results, (6) any documentation of the M&S, including technical review documentation.*
>
> *Rationale: Due to the inexact nature of all M&S in replicating real word systems, explicit reporting of key M&S information is required to facilitate clear understanding of risks associated with M&S results.*

5.5 COLLABORATIVE SIMULATION TECHNOLOGIES

Because the Gateway elements will be developed by multiple providers staggered over a significant period of time, mechanisms must be codified to ensure that models, simulations, and their supporting data can be exchanged between NASA and its commercial and international partners. Complicating the matter is that each provider is likely to have its own modeling tools, simulation execution environment, and data protection requirements.

The Gateway program intends to leverage international standards to ensure that models and simulations can be used collaboratively to satisfy programmatic needs while allowing appropriate protection of intellectual property.

> *[**GMS 27**] For distributed simulations, the participating simulations shall satisfy IEEE 1516-2010, IEEE Standard for Modeling and Simulation High Level Architecture and the Simulation Interoperability Standards Organization (SISO) Space Reference Federation Object Model (FOM).*
>
> *Rationale: The High Level Architecture mechanism is widely used for cases where loosely coupled simulated vehicles can be tied together in a common environment with known interactions. Examples include large-scale joint NATO military exercises involving hundreds of simulated vehicles, as well as spacecraft training operations involving ISS and international and commercial partners. Ref: https://standards.ieee.org/standard/1516-2010.html*
>
> *The Federation Object Model provides a mechanism to define the types of data that can be exchanged and interactions that can occur between modeled elements in separate HLA-enabled simulations. The Space Reference FOM specifies space-unique data and interactions, and has been developed by an international M&S community.*
>
> *Ref: https://www.sisostds.org/StandardsActivities/DevelopmentGroups/SRFOMPDGSpaceReferenceFederationObjectModel.aspx*

*[**GMS 28**] For simulations that involve model object code linked together from disparate sources, participating models shall satisfy the Functional Mockup Interface 2.0 standard on a Linux host with C/C++ based object code. (Ref: https://fmi-standard.org)*

Rationale: FMI is an open, international standard that allows pre-compiled object code from multiple sources to be linked into a common executable. Models may be delivered without delivering associated source code.

5.6 PROJECTED SIMULATION NEEDS

To provide systems engineering performance analysis capabilities, support flight software development, test element interfaces and functional performance, perform integrated V&V analysis, perform mission planning analysis, and support crew and flight controller training activities.

*[**GMS 29**] L3 Element cross-program M&S shall be developed by each of the L3 Elements to support planned systems engineering performance analysis.*

Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated simulation for systems engineering performance analysis.

*[**GMS 30**] L3 Element cross-program M&S shall be developed by each of the L3 Elements to support flight software development activities.*

Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated simulation for flight software development.

*[**GMS 31**] L3 Element cross-program M&S shall be developed by each of the L3 Elements to test element interfaces and functional performance.*

Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated testing of interfaces and functional performance.

*[**GMS 32**] L3 Element cross-program M&S shall be developed by each of the L3 Elements to perform integrated V&V analysis.*

Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated verification and validation testing.

*[**GMS 33**] L3 Element cross-program M&S shall be developed by each of the L3 Elements to perform mission planning analysis.*

Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated simulation for mission planning analysis.

*[**GMS 34**] L3 Element cross-program M&S shall be developed by each of the L3 Elements to support crew and flight controller training activities.*

Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated simulation for integrated training activities.

As described in section 4.1 these M&S will be delivered and matured incrementally through the program life cycle.

*[**GMS 35**] The Gateway Modeling and Simulation Working Group shall establish a list of models deemed necessary to share between Gateway elements and recommend contractual requirements to be imposed on element providers.*

Rationale: Contractual requirements are necessary to ensure that models are developed effectively and efficiently through the life cycle of the elements. With specific contractual terms, third-party organizations are required to track the development of space equipment and model its capabilities, often without direct access to detailed design data, at great expense.

*[**GMS 36**] Each element shall provide models of the behavior of each of its systems, including nominal and off nominal scenarios and associated data to the program for incorporation into integrated vehicle simulations.*

Rationale: Integrated vehicle simulations including for example, propulsion, power, thermal, crew systems, crew health & performance, and life support system models are used throughout the programmatic life cycle for systems engineering, analysis and design, test and verification, training, and mission operations. Models that support integrated vehicle simulations (see definition in section A2.0 Glossary of Terms) are capable of properly propagating behaviors across element and subsystem boundaries.

*[**GMS 37**] Each element shall provide models of the geometry and dynamics of the system, including nominal and off nominal scenarios, for incorporation into integrated vehicle simulations.*

Rationale: Data is needed to assess integrated performance including geometry models for various analyses. For example, contact and alignment data is needed to assess integrated performance including geometry models for various line-of-sight analyses. Models that support integrated vehicle simulations (see definition in section A2.0 Glossary of Terms) are capable of properly propagating behaviors across element and subsystem boundaries.

*[**GMS 38**] Each element shall update its delivered models in the L2 repository prior to the start of integrated analysis, verification and operational cycle activities with any mid-cycle release requirements accommodated by agreements between stakeholders.*

Rationale: The proposed design of the vehicle will change throughout its development, and the delivered models need to be updated to support integrated vehicle studies in support of analysis cycles.

*[**GMS 39**] Each element shall produce an emulator that satisfies its data interfaces to other elements and exchanges realistic data with those elements.*

Rationale: Element emulators provide the functionality and data interfaces necessary to support verification of the interfaces and the integrated performance of the vehicle stack before deployment. It is best practice to establish the emulator development early in the program lifecycle to support development of flight software as well as testing of interfaces between systems.

*[**GMS 40**] Each element shall deliver a copy of its emulator to each element plus one to the program.*

Rationale: At a minimum, each element requires an emulator of its adjacent elements in order to test its interfaces and supporting functionality. The program requires a complete set of emulators to evaluate the complete vehicle stack interfaces and functionality.

*[**GMS 41**] Each element shall keep its delivered emulators up to date throughout the program lifecycle.*

Rationale: The data interfaces and functionality of the vehicle represented in the emulator will change frequently throughout the vehicle development. Updating the emulators helps to identify problems in inter-vehicle interfaces and functionality as early as possible.

5.7 GATEWAY M&S PRODUCTS

This section provides a listing of M&S products required to support cross-program M&S exchange. Many of the M&S products will be provided by the program elements, much of the standard tailoring and M&S database population will be shared responsibility of the elements and the M&S SM and staff, and the creation of the M&S database and programmatic tracking capabilities will be provided by the M&S SM and supporting staff. The items in this table are organized by responsible parties and are not meant to represent a chronological order of occurrence.

Responsible Party	Product Name	Description	Rationale
L3 Element Projects	Cross-Program Element M&S	Element owned/developed M&S including supporting documentation, evidence and metadata that is exchanged between elements and is integrated to build the L2 integrated simulation capability	Element M&S are exchanged and integrated into L2, physics-based simulations that provide engineering-level data to inform the SE&I decision processes for Gateway design, development, test, operations, and maintenance.
Developer in cooperation with Analyst. Approval from TA and PM (L2 delegated to L3)	NASA-STD-7009 Tailoring	Criticality Based Tailoring of Standard for Model and Simulations	Medium and low criticality M&S do not require full application of requirements. Medium should be tailored as appropriate while low should be viewed as “best practices”. Requirements are fully applied for high criticality M&S.
L3 Element Projects / Gateway M&S SM	M&S Database	Provides a complete listing for each cross-program M&S including programmatic and compliance metadata.	Provides insight into current, in-use cross-program M&S pedigree. Supports dependency management and reporting. Allows insight to all cross-program M&S in use and reporting on all critical cross-program M&S. L2 M&S SM will develop and maintain the MSDB which will be populated with M&S that primarily come from L3 Element Projects
Developer and Analyst	Requirements	Capture and documentation of M&S development and integration needed to meet integrated analysis, test, training and operations activities	The analyst and developer must define requirements sufficient for successful M&S implementation and testing and to estimate needed budget and schedule allocations
Gateway M&S SM	M&S Infrastructure	Infrastructure capabilities will be required including but not limited to, tooling to support M&S sharing via MSDB	To provide integrated M&S capability in support of L2 activities as well as enabling exchange of M&S between element projects.
Gateway M&S SM	Gap Analysis	Cross-program M&S needs and dependencies are identified through program planning. These are assessed against existing and planned M&S capabilities to identify what may be leveraged and/or what capabilities need to be developed and or rigor increased. If needed capabilities require effort, they are included in the GAP analysis report and are prioritized and dispositioned for work	All needed capabilities will likely not be mature to meet needs per program schedules. Early identification of these gaps provides an opportunity to include development efforts in program resource planning.

Gateway M&S SM	M&S Schedule	M&S master schedule, developed with stakeholders, that details deliveries for major milestones, highlights cross-program M&S dependencies, and incorporates L2 development and integration efforts.	Planning development activities, tracking progress and dependencies and reporting to program management to provide insight and allow for adjustments as needed.
Gateway M&S SM	L2 Simulation Capability	L2, cross-domain integrated simulation of the Gateway Elements, space environment, and mission operations scenarios	This integrated simulation brings in principal Elements of the Gateway into physics-based simulations that provide engineering-level data to inform the SE&I decision processes for Gateway design, development, test, operations, and maintenance.
Gateway M&S SM	M&S Risk Tracking and Reporting	Technical, cost and schedule risks are identified and tracked as a part of normal business rhythms.	Tracking M&S risks allows the M&S community to work mitigations within cost and schedule constraints. When mitigations exceed cost or schedule constraints they are communicated per the Gateway Risk Management Plan (DSG-PLAN-006) defined processes and forums.

TABLE 5.7 GATEWAY M&S PRODUCTS

APPENDIX A
ACRONYMS AND ABBREVIATIONS AND GLOSSARY OF TERMS

A1.0 ACRONYMS AND ABBREVIATIONS

ADD	Architecture Definition Document
BAA	Broad Agency Announcement
CR	Change Request
CAIB	Columbia Accident Investigation Board
CDM	Configuration and Data Management
CM	Configuration Management
CR	Change Request
DDT&E	Design, Development, Test & Evaluation
DE	Domain Expert
FOM	Federation Object Model
GVCB	Gateway Vehicle Control Board
HLA	High Level Architecture
HLS	Human Lander System
IAC	Integrated Analysis Cycle
IP	Intellectual Property
JICB	Joint Integration Control Board
L2	Level 2
L3	Level 3
M&S	Modeling and Simulation
MSDB	Modeling and Simulation Data Base
MSWG	Modeling and Simulation Working Group
OPR	Office of Primary Responsibility
PM	Program Manager
SE&I	Systems Engineering and Integration
SISO	Simulation Interoperability Standards Organization
SM	System Manager
TA	Technical Authority
VAC	Verification Analysis Cycle
VI	Vehicle Integration

A2.0 Glossary of Terms

Term	Description
Collaborative Simulation	Simulation approach that enables distributed simulation and simulation exchange
Element	An organizational unit responsible for developing significant capabilities for the Gateway.
Emulation	The use of an M&S to reproduce the function or action of another system
Integrated Vehicle Simulation	A simulation that contains multiple subsystems with physically correct interactions between them.
Intended Use	The expected purpose and application of an M&S
Modeling	the act of creating a representation of a system
Metadata	Descriptive information that provides information about other data or activities
Proposed Use	A desired specific application of an M&S

Simulation	The imitation of the behavioral characteristics of a system, entity, phenomenon, or process
Verification	The process of determining the extent to which an M&S is compliant with its requirements and specifications as detailed in its conceptual models, mathematical models, or other constructs
Validation	The process of determining the degree to which a model or a simulation is an accurate representation of the real world from the perspective of the intended uses of the M&S.
Waiver	A documented authorization intentionally releasing a program or project from meeting a requirement

APPENDIX B OPEN WORK

B1.0 TO BE DETERMINED

The table To Be Determined Items lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is numbered based on the document number, including the annex, volume, and book number, as applicable (i.e., **<TBD-XXXXX-001>** is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

TABLE B1-1: TO BE DETERMINED ITEMS

TBD	Section/Table/ Figure	Description

B2.0 TO BE RESOLVED

The table To Be Resolved Issues lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBR issue is numbered based on the document number, including the annex, volume, and book number, as applicable (i.e., **<TBR-XXXXX-001>** is the first unresolved issue assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

TABLE B2-1: TO BE RESOLVED ISSUES

TBR	Section/Table/ Figure	Description

B3.0 ACTIONS

The table Open Actions lists the specific actions in the document to be addressed in subsequent revisions. The “*** Action:” is inserted as a placeholder wherever the required data is needed. As each Action is resolved, the updated text is inserted in each place that “*** Action:” appears in the document and the action is removed from this table. As new “*** Action:” are assigned, they will be added to this list in accordance with the above described numbering scheme. Original “*** Action:” will not be renumbered.

TABLE B3-1: OPEN ACTIONS

Action	Section	Description

APPENDIX C METADATA

C 1.0 METADATA REQUIREMENTS

This section defines metadata required by life cycle activity. Increased rigor is applied as the program progresses. “M” indicates the metadata should be mature, “A” indicates the metadata item should be addressed but may not be completely mature, “O” indicates the metadata item may be addressed but is optional. Some items in the “7009 Compliance” section may not be required for non-critical, cross-program M&S as this document provides a tailoring to NASA-STD-7009 for medium and low criticality models. In many cases the data captured in the metadata field in the MSDB may be a pointer to documentation contained in the delivery package.

	Metadata ID	Description	Trade	Design	Test	Ops	Responsible Party	NASA-STD-7009 Traceability
Registration	Model Name	Name of cross-program M&S	M	M	M	M	Developer	N/A
	MSDB Unique Identifier	ID assigned when entered in MSDB	M	M	M	M	DSG M&S SM	N/A
	Version/Revision	Version of M&S being released for use	M	M	M	M	Developer	N/A
	Metadata Revision	Version of metadata update	M	M	M	M	Developer	N/A
	Release Date	Current date for release for use	M	M	M	M	Developer	N/A
	Intended Use	Intended/Proposed Use for M&S	M	M	M	M	Analyst	NASA-STD-7009 M&S 8, 22
	Element Subsystem	Name of subsystem modeled	M	M	M	M	Developer	N/A
	Life Cycle activity	Life cycle activity M&S exchange supporting	M	M	M	M	Analyst	N/A
	Model Point of Contact	Identified person for questions and information about M&S	M	M	M	M	Developer	N/A
Programmatic	Schedule	Agreed to dates for M&S delivery including any incremental deliveries	M	M	M	M	Developer	N/A
	Resource Exchange Agreement	Description of resources to be exchanged	A	M	M	M	Developer	N/A
	Delivery Contents	Full listing of all delivery contents	M	M	M	M	Developer	N/A
	Dependencies	Dependent organizations, analysis, test and/or development and integration tasks	A	A	M	M	Developer	N/A
	Feedback Frequency	Frequency using organization submits modifications to developer organization for incorporation	M	M	M	M	Developer	N/A
Collab	Computer Performance	CPU performance requirements	M	M	M	M	Developer	N/A
	Operating System	Specification of operating system in use	M	M	M	M	Developer	N/A
	Required Software	Listing of any software required in addition to the M&S	M	M	M	M	Developer	N/A
7009 Compliance	RWS	Description of real-world system used to develop model including pedigree info	A	A	M	M	Developer	NASA-STD-7009 M&S 10
	Criticality	M&S criticality assessment result	M	M	M	M	Analyst	NASA-STD-7009 M&S 6
	Tailored 7009 Compliance	TA Approved 7009 compliance matrix (if medium or low criticality)	A	A	M	M	Analyst	NASA-STD-7009 M&S 2
	Acceptance Criteria	Criteria to accept the model for intended use and indication if any not achieved in final delivery	A	M	M	M	Analyst	NASA-STD-7009 M&S 8
	Technical Description of Model	Basic structure and mathematics of M&S	M	M	M	M	Developer	NASA-STD-7009 M&S 12
	Assumptions	Defined assumptions and abstractions w/ rationale	M	M	M	M	Developer	NASA-STD-7009 M&S 11
	Permissible Uses	Permissible relevant uses of M&S	O	A	M	M	Developer	NASA-STD-7009 M&S 14
	Risk	Risk(s) associated with M&S based analysis	O	A	M	M	Analyst	NASA-STD-7009 M&S 39
	Limits of Operation	Limits of operation of model e.g. Boundary conditions	O	A	M	M	Developer	NASA-STD-7009 M&S 13
	Verification	Domain of verification and verification evidence	A	M	M	M	Developer	NASA-STD-7009 M&S 15, 16
	Validation	Domain of validation and validation evidence	O	A	M	M	Developer	NASA-STD-7009 M&S 17, 18
	Development Uncertainty	Uncertainties in referent data, incorporated in model or included in M&S.	O	A	M	M	Developer	NASA-STD-7009 M&S 19, 20, 21
	Appropriateness for Use	Endorsement that M&S is sufficient for user requirements	M	M	M	M	Analyst	NASA-STD-7009 M&S 23
	Setup Information	Rationale for setup and execution of the simulation and analysis	O	A	M	M	Analyst	NASA-STD-7009 M&S 25
	Usage Uncertainty	Quantitative or qualitative description of uncertainty in M&S results in input, results or quantities derived from M&S results and any processes and rationale for characterizing uncertainty or, statement that not available	O	A	M	M	Analyst	NASA-STD-7009 M&S 28, 29, 34

7150.2 Compliance	Use Limitations	Analysis conducted within limits or placard application	A	M	M	M	Analyst	NASA-STD-7009 M&S 26
	Input Pedigree	M&S Input data description including pedigree	O	A	M	M	Analyst	NASA-STD-7009 M&S 24
	Warnings and Errors	Warnings encountered during execution of computational M&S	A	M	M	M	Analyst	NASA-STD-7009 M&S 27, 32
	Sensitivity Analysis	Results of any sensitivity analysis performed	O	A	M	M	Analyst	NASA-STD-7009 M&S 30
	Credibility Assessment	Results of credibility assessment for all factors	A	A	M	M	Analyst	NASA-STD-7009 M&S 31, 35
	Personnel Qualifications	Education, training and experience for full M&S lifecycle development and use	O	A	M	M	All	NASA-STD-7009 M&S 37
	CDM specification	Configuration specification to rebuild, execute, access all delivery items	M	M	M	M	Analyst	NASA-STD-7009 M&S 8
	Unfavorable Outcomes	Any unachieved acceptance criteria, unfavorable outcomes from use assessment or setup/execution assessment	O	A	M	M	Analyst	NASA-STD-7009 M&S 32
	M&S Documentation	Descriptions of M&S functionality and usage information	O	A	M	M	Developer	NASA-STD-7009 M&S 38
	Technical Reviews	All technical review information	A	M	M	M	DSG M&S SM	NASA-STD-7009 M&S 9, 36
	Software Classification	Software classification designated per NPR 7150.2 process	A	A	M	M	Developer	N/A
	Safety Criticality Rating	Software safety criticality rating designated per NPR 7150.2 process	A	A	M	M	Developer	N/A

APPENDIX D NASA-STD-7009 COMPLIANCE MATRIX

The compliance matrix below describes a graduated approach to NASA-STD-7009 compliance based on the results of the criticality assessment. All items denoted with a "Y" are required to be implemented. Cases where compliance needs to be considered are denoted with a "C". All items in the list are considered best practices, so an "N" should not be taken to mean that a requirement should not be addressed at all.

For M&S addressing low criticality decisions, much of the standard is not required. For high criticality cases, the full set of 7009 requirements should be addressed. For medium criticality decisions, coarse tailoring should be considered by including or waiving entire sections en-masse (e.g. General M&S Development, Verification, Validation, Uncertainty Characterization in Development, M&S Use, Uncertainty Characterization in Use, Sensitivity Analysis, Credibility Assessment, Results Reporting) as makes sense per the analysis being performed.

Req ID	Description	Requirement	Low	If No, Rationale	Med	If No, Rationale	High	Compliance Notes
NASA-STD-7009					Assessed Criticality			
M&S 6	General M&S Programmatics	Shall perform and document the criticality assessment for the M&S.	Y	A criticality assessment and standard applicability should be determined for each M&S product by the Program Technical Authority or designee.	Y		Y	Section 5.4.2 Criticality Assessment,
M&S 7	General M&S Programmatics	Shall identify and document if the M&S is in scope of this NASA Technical Standard.	Y	An in-scope determination should be made for each M&S product by Program Management or designee.	Y		Y	Section 5.4.1 Identification of CP M&S
M&S 8	General M&S Programmatics	Shall define the objectives and requirements for M&S products including the following: (1) The acceptance criteria for M&S products, including any endorsement for the M&S. (2) Intended use. *The intended uses may be updated throughout the model development.* (3) Metrics (programmatic and technical). (4) Verification, validation, and uncertainty characterization (see [M&S 15-16], [M&S 17-18], [M&S 19-21]). (5) Reporting of M&S information for critical decisions (see [M&S 32-39]). (6) Configuration management (CM) (artifacts, timeframe, processes) of M&S.	N	1	C	Items 1, 2 and 4 apply for medium criticality decisions. Details on metrics, reporting and CM are not applicable for medium criticality decisions as they will not be monitored by PM/TA as critical	Y	Section 5.3 Roles and Responsibilities
M&S 9	General M&S Programmatics	Shall document any technical reviews accomplished in regard to the development, management (control), and use of the M&S.	N	1	C	In the medium classification, there may not have been specific technical reviews related to the simulation product. Consideration should be given as to whether the M&S could be used for high criticality decisions.	Y	Section 5.4.4.3 M&S Package Approval and Delivery
M&S 10	General M&S Development	Shall document the relevant characteristics, including data, about the RWS used to develop the model, including its pedigree (see Data Pedigree in [NASA-STD-7009] Appendix E).	N	1	C	If existing M&S is being reused, the requestor should determine whether	Y	Appendix C, Metadata: RWS

						such documentation is necessary and should be produced if non-existent. If new M&S is being developed, this documentation should be required.		
M&S 11	General M&S Development	Shall document the assumptions and abstractions underlying the M&S, including their rationales.	N	1	C		Y	Appendix C Metadata: Assumptions
M&S 12	General M&S Development	Shall document the basic structure and mathematics of the model (e.g., equations solved, behaviors modeled, and conceptual models).	N	1	C		Y	Appendix C Metadata: Technical Description of Model
M&S 13	General M&S Development	Shall document the limits of operation (e.g., boundary conditions) of models.	N	1	N	[2]	Y	Appendix C Metadata: Limits of Operation
M&S 14	General M&S Development	Shall document the permissible uses of the M&S.	N	1	Y		Y	Appendix C Metadata: Permissible Uses
M&S 15	M&S Verification	Shall verify all models.	N	1	C	If existing M&S is being reused, the requestor should determine whether verification against new programmatic M&S requirements is necessary.	Y	Appendix C Metadata: Verification
M&S 16	M&S Verification	Shall document the domain of verification of all models.	N	1	C	See Rationale for M&S 15	Y	Appendix C Metadata: Verification
M&S 17	M&S Validation	Shall validate all models.	N	1	C	If existing M&S is being reused, the requestor should determine whether validation against additional conditions is necessary. If new M&S is being developed, validation against conditions specified by the requestor and/or M&S developer should be required.	Y	Appendix C Metadata: Validation
M&S 18	M&S Validation	Shall document the domain of validation of all models.	N	1	C	See Rationale for M&S 17	Y	Appendix C Metadata: Validation
M&S 19	Uncertainty Characterization in M&S Development	Shall document any processes and rationale for characterizing uncertainty in the referent data.	N	1	C	The need for uncertainty characterization should be specified by the requestor.	Y	Appendix C Metadata: Development Uncertainty
M&S 20	Uncertainty Characterization in M&S Development	Shall explain and document any mechanisms or constructs related to the incorporation or propagation of uncertainty in the model.	N	1	C	See Rationale for M&S 19	Y	Appendix C Metadata: Development Uncertainty

M&S 21	Uncertainty Characterization in M&S Development	Shall document any uncertainties (qualitatively described or quantitative) incorporated into the M&S.	N	1	C	See Rationale for M&S 19	Y	Appendix C Metadata: Development Uncertainty
M&S 22	M&S Use Requirements	Shall document the proposed use(s) of the M&S.	N	1	Y		Y	Appendix C Metadata: Intended Use
M&S 23	M&S Use Requirements	Shall perform and document an assessment of the appropriateness of the M&S relative to its proposed use.	N	1	Y		Y	Appendix C Metadata: Appropriateness for Use
M&S 24	M&S Use Requirements	Shall document data used as input to the M&S, including its pedigree (see Input Pedigree in Appendix E).	N	1	Y		Y	Appendix C Metadata: Input Pedigree
M&S 25	M&S Use Requirements	Shall document the rationale for the setup and execution of the simulation and analysis.	N	1	N	[2]	Y	Appendix C Metadata: Setup Information
M&S 26	M&S Use Requirements	Shall do either of the following: (1) Ensure that simulations and analyses are conducted within the limits of operation of the models, or (2) Placard the simulation and analysis results with a warning that the simulation may have been conducted outside the limits of operation and include the type of limit that may have been exceeded, the extent that the limit might have been exceeded, and an assessment of the consequences of this action on the M&S results.	N	1	Y		Y	Appendix C Metadata: Use Limitations
M&S 27	M&S Use Requirements	Shall document and explain any observed warning and error messages resulting from the execution of the computational M&S.	N	1	N	[2]	Y	Appendix C Metadata: Warnings and Errors
M&S 28	Uncertainty Characteristics in M&S Use	Shall document any processes and rationale for characterizing uncertainty in: (1) The input to an M&S. (2) The results from an M&S. (3) The quantities derived from M&S results.	N	1	C	The need for uncertainty characterization should be specified by the requestor.	Y	Appendix C Metadata: Usage Uncertainty
M&S 29	Uncertainty Characteristics in M&S Use	Shall document any uncertainties (qualitatively described or quantitative) in: (1) The input to an M&S. (2) The results from an M&S. *This includes any Model Uncertainty Factors incorporated into the M&S as well as any Factors of Safety (FS) that are intended to cover uncertainties in the model or simulation. The uncertainties those factors are intended to address should also be documented.* (3) The quantities derived from M&S results.	N	1	C	The need for uncertainty characterization should be specified by the requestor.	Y	Appendix C Metadata: Usage Uncertainty
M&S 30	M&S Sensitivity Analysis	The responsible party shall document the extent and results of any sensitivity analyses performed with the M&S.	N	1	C	The need for sensitivity analysis should be specified by the requestor	Y	Appendix C Metadata: Sensitivity Analysis
M&S 31	M&S Results Credibility Assessment	The responsible party shall assess the credibility of M&S results for each of the factors described in Appendix E.	N	1	C	The need for a credibility assessment should be specified by the requestor.	Y	Section 5.4.5 M&S Credibility Assessment, Appendix C Metadata: Credibility Assessment
M&S 32	M&S Results Reporting	Shall include explicit warnings for any of the following occurrences, accompanied by at least a qualitative estimate of the impact of the occurrence:	N	1	C	The types of reporting should be defined based on the	Y	Section 5.4.5 M&S Credibility Assessment,

		(1) Any unachieved acceptance criteria (as specified in [M&S 8 (1)]). (2) Violation of any assumptions of any model (as specified in [M&S 11]). (3) Violation of the limits of operation (as specified in [M&S 13]). (4) Execution warning and error messages (see [M&S 27]). (5) Unfavorable outcomes from the proposed use assessments (described in [M&S 23]). (6) Unfavorable outcomes from any setup/execution assessments (described in [M&S 25]). (7) Waivers to any of the requirements in this NASA Technical Standard.				requestor choices for documentation, uncertainty characterization, and credibility analysis.		Appendix C Metadata: Unfavorable Outcomes
M&S 33	M&S Results Reporting	Shall include an estimate of results uncertainty, as defined in [M&S 29 (1)-(3)], in one of the following ways: (1) A quantitative estimate of the uncertainty in the M&S results, or (2) A qualitative description of the uncertainty in the M&S results, or (3) A clear statement that no quantitative estimate or qualitative description of uncertainty is available.	N	1	C	See Rationale for M&S 32	Y	Section 5.4.5 M&S Credibility Assessment, Appendix C Metadata: Usage Uncertainty
M&S 34	M&S Results Reporting	Shall include a description of any processes used to obtain the estimate of uncertainty as defined in [M&S 28 (1)-(3)].	N	1	C	See Rationale for M&S 32	Y	Section 5.4.5 M&S Credibility Assessment, Appendix C Metadata: Usage Uncertainty
M&S 35	M&S Results Reporting	Shall include the assessment of credibility for the M&S results for each factor specified in [M&S 31	N	1	C	See Rationale for M&S 32	Y	Section 5.4.5 M&S Credibility Assessment, Appendix C Metadata: Credibility Assessment
M&S 36	M&S Results Reporting	Shall include the findings from any technical reviews accomplished in regard to the development, management (control), and use of the M&S.	N	1	C	If, for med criticality decision, technical reviews were accomplished and documented they should be reported	Y	Section 5.4.5 M&S Credibility Assessment, Section 5.4.4.3 M&S Package Approval and Delivery, Appendix C Metadata: Technical Reviews
M&S 37	M&S Results Reporting	Shall include the qualifications of the developers of the M&S and the users, operators, and/or analysts involved in producing the results from the M&S, including, but not limited to, their relevant education, training, and experience.	N	1	N	2	Y	Section 5.4.5 M&S Credibility Assessment, Appendix C Metadata: Personnel Qualifications
M&S 38	M&S Results Reporting	Shall show what aspects of modeling and simulation are documented, as shown in Appendix A.	N	1	N	2	Y	Section 5.4.5 M&S Credibility Assessment, Appendix C Metadata: M&S Documentation
M&S 39	M&S Results Reporting	Shall include an assessment of and rationale for the risks associated with the use of the M&S-based analysis.	N	1	Y	2	Y	Section 5.4.5 M&S Credibility Assessment, Appendix C Metadata: Risks

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[1] The 7009 Standard is not considered applicable for low criticality decisions but does provide a good set of best practices for M&S development. If the resultant M&S may be used for future higher criticality decisions, the Program Technical Authority should consider whether medium or high criticality standards should be applied with the awareness that higher criticality requirements will induce both schedule and cost impacts to the M&S development, use, and assessment.

[2] While not strictly required for medium criticality M&S, may still be good practice. Decision makers within rights to ask questions regarding these items.

APPENDIX E GATEWAY MODELING AND SIMULATION REQUIREMENTS

Requirement ID	Requirement Text
GMS 1	*The PM shall make delegates aware of full responsibilities listed below to ensure compliance.* *Rationale: Delegation to the lowest level possible while achieving requirements is optimal but successful delegation is grounded in the assumption that delegates understand all expectations and responsibilities.*
GMS 2	*The TA shall make delegates aware of full responsibilities listed below to ensure compliance.* *Rationale: Delegation to the lowest level possible while achieving requirements is optimal. Successful delegation is grounded in the assumption that delegates understand all expectations and responsibilities.*
GMS 3	*The M&S SM shall ensure cross-program M&S processes and products support stakeholder needs and communicate cross-program M&S progress, issues and risks to program management.* *Rationale: To support cross-program M&S exchange, stakeholder needs must be understood. Informing program management of issues, risks and progress allows for adjustment to program plans as needed*
GMS 4	*M&S SM shall ensure NASA-STD-7009 compliance as appropriate based on M&S criticality and life cycle phase.* *Rationale: As cross-program M&S are exchanged, requirements compliance needs to be understood and documented to clarify expectations and allow for adequate planning. If gaps are discovered, they are documented so that all parties understand the pedigree of the M&S.*
GMS 5	*M&S SM shall stand up a Modeling and Simulation Working Group to review criticality assessments, determine which models and simulations should be shared between elements, oversee creation of the Modeling and Simulation Database, and verify that the database is properly populated and maintained.* *Rationale: Coordination of cross-program M&S stakeholder needs including identifying cross-program M&S and reviewing criticality assessments ensures M&S activities are not duplicated, promotes leveraging existing capabilities and provides guidance through the criticality assessment process.*
GMS 6	*M&S SM shall serve as the signature authority on proposed waivers to requirements contained in this plan.* Rationale: Waiver approval authority resides with the PM and TA (delegated to the M&S SM). As cross-program M&S are developed there may be instances where an M&S does not currently or cannot meet the Gateway M&S Plan requirements. In these cases, a waiver must be requested by the M&S owner with adequate rationale and description of related risk. The M&S SM will evaluate the waiver and, if approved, release the requester from meeting the requirement
GMS 7	*The M&S DE shall provide input to program management and the TA to assess the influence an M&S has on critical decisions.* *Rationale: Criticality determination resides with the PM and TA who specify the consequence*
GMS 8	*The M&S Working group shall serve as the forum to coordinate stakeholder needs, provide guidance for cross-program M&S processes and requirement implementation, identify cross-program M&S dependencies and track cross-program M&S progress.* *Rationale: Successful model exchange is enabled through vetting of stakeholder needs, execution of a common set of process and understanding cross-program dependencies. The working group is chartered with technical, schedule and budget decision making capability as delegated by the Gateway Vehicle Control Board (GVCB)*
GMS 9	*The developer and analyst in cooperation with the M&S SM shall analyze the identified M&S need against existing and planned M&S capabilities, map capabilities to needs, identify dependencies and gaps in capability, and ensure efforts are not duplicated across the program.* *Rationale: The functional capabilities of existing and planned M&S as well as the rigor applied during development and previous use activities may be different from the identified need.*
GMS 10	*The analyst shall assess identified M&S capabilities and proposed development to close any capability gaps and evaluate appropriateness for proposed use.*

	Rationale: Current M&S state and any proposed modifications to meet proposed use need to be evaluated so that resources are applied appropriately to meet analysts' needs.
GMS 11	*The developer and M&S SM in cooperation with SMA shall consider the M&S "final use" early in the life cycle.* *Rationale: Early consideration of "final use" allows for proper planning for NASA-STD-7009 and NPR 7150.2 compliance.*
GMS 12	*The Domain Experts, M&S Users, and M&S SM shall use the criticality assessment method described in in NASA-STD-7009 Appendix D with additional consideration for (1) the immediacy of consequence mentioned above and (2) potential future use of the model. [NASA-STD-7009 M&S 6]* *Rationale: Criticality determination resides with the PM (delegated to the M&S SM) and TA who specify the consequence. Assessing the influence of an M&S on a decision is well served by domain expertise. The immediacy of consequence should be considered when evaluating criticality. If the decision consequence is not immediate, consideration should be given to reducing the assessed criticality unless no further analysis is planned related to the decision. Conversely, if low criticality M&S is expected to be used for higher criticality decisions at a future point in the project, consideration should be given to initially designating it as medium criticality. In either case, the life cycle development plan for the model should consider its future use.*
GMS 13	*The M&S System manager shall mark all critical cross-program M&S in the MSDB.* *Rationale: Easy identification of critical M&S allows for clear insight to dependencies. All organizations using critical cross-program M&S need insight to effectively plan, identify risks and monitor progress.*
GMS 14	*[GMS 14] The Gateway program and L3 projects shall apply the tailoring in Appendix D of this document as the Gateway specific implementation of NASA-STD-7009.* *Rationale: To provide a graduated approach to NASA-STD-7009 compliance based on criticality assessment results. For M&S assessed as high criticality the full complement of requirements apply while for lesser criticality M&S a tailored set are applied.*
GMS 15	*The M&S SM shall register all M&S identified as cross-program in the MSDB. An MSDB identifier shall be assigned and the registration metadata shall be completed.* *Rationale: Cataloging of all M&S used for cross-program activities allows for centralized exchange and insight into available capabilities, dependencies and compliance status.*
GMS 16	*The M&S SM shall complete the programmatic metadata in the MSDB.* *Rationale: Capture of program agreements and dependencies allows for planning and tracking throughout the program life cycle.*
GMS 17	*The M&S SM shall complete the collaborative simulation metadata in the MSDB.* *Rationale: To successfully exchange M&S to be used collaboratively to satisfy programmatic needs these details must be documented for participants.*
GMS 18	*The M&S SM shall consider final use and apply the NASA-STD-7009 requirements as prescribed in Metadata, Appendix C of this plan to allow for incremental requirements compliance.* *Rationale: Incremental compliance is supported through a graduated approach through the life cycle. The Metadata detailed in Appendix C includes the information, supporting documentation and evidence required for compliance per life cycle phase (Trades, Design, Test, Operations).*
GMS 19	*The M&S WG shall establish target credibility factor expectations [NASA-STD-7009, Appendix E, Table 3] for each development stage of medium and high criticality models.* *Rationale: cross-program M&S user requirements will evolve through the program life cycle. To support accurate M&S planning to meet user needs the M&S WG will determine appropriate targets (numeric scores) for credibility factors based on life cycle phase and intended use.*
GMS 20	*The M&S SM shall capture 7150.2 classification and safety criticality rating information in MSDB metadata.* *Rationale: Software classification and safety criticality rating are key elements to criticality assessments.*
GMS 21	*The Gateway M&S SM shall report all critical cross-program M&S to program management and identify and communicate cross-program M&S dependencies to ensure that they are incorporated into program baseline planning activities.*

	Rationale: To provide required M&S capabilities M&S development, verification and validation requirements must be understood and accounted for in program planning activities. Cross-program M&S dependencies must be understood during planning activities to ensure stakeholder needs are met.
GMS 22	*The M&S SM shall provide access control to the L2 MSDB and the L2 repository to strictly limit access to only mutually approved parties.* *Rationale: International Partners and corporations have export control and proprietary interests that must be accommodated to enable cross-program M&S exchange.*
GMS 23	*The Gateway M&S SM shall follow collaborating commercial and International Partner processes for exchange of data and shall ensure that data exchange compliance is achieved to enable collaborative simulation and data exchange.* *Rationale: When centralized M&S exchange and storage is not feasible, Gateway M&S SM will ensure the ability to perform collaborative simulation and data exchange.*
GMS 24	*The M&S System Manager shall store cross-program M&S deliveries in the L2 repository under Configuration and Data Management (CDM) control. It will be made available for release with access provided in a manner that adheres to the IP Security Management process described in the previous section.* *Rationale: Central storage and configuration management enables centralized M&S exchange.*
GMS 25	*L2 and Element organizations delivering M&S to the L2 repository shall configuration manage their M&S within originator organizations such that CM configuration specification provides all items necessary for a receiver to rebuild, execute, reproduce results and access all supporting documentation included in the delivery.* *Rationale – All M&S products, regardless of origination, are provided to ensure full product availability and function.*
GMS 26	*Using organizations shall submit all modifications, enhancements and fixes back to the developing organization for incorporation in future deliveries per the agreed upon frequency.* *Rationale: This feedback process benefits both the developing and using organizations. By frequently providing modifications back to the developer organization, the changes and improvements can be folded back into their product in an incremental manner and the using organization can expect smoother efforts to step up to more mature versions of the deliverable with their modifications included as part of the configuration managed package. This process prevents diverging products. If cases arise where proprietary data is inserted into a delivered model set, the vendor and receiver will need to come to an agreement on how to properly handle the data and manage redelivery.*
GMS 27	*For distributed simulations, the participating simulations shall satisfy IEEE 1516-2010, IEEE Standard for Modeling and Simulation High Level Architecture and the Simulation Interoperability Standards Organization (SISO) Space Reference Federation Object Model (FOM).* *Rationale: The High Level Architecture mechanism is widely used for cases where loosely coupled simulated vehicles can be tied together in a common environment with known interactions. Examples include large-scale joint NATO military exercises involving hundreds of simulated vehicles, as well as spacecraft training operations involving ISS and international and commercial partners. Ref: https://standards.ieee.org/standard/1516-2010.html* *The Federation Object Model provides a mechanism to define the types of data that can be exchanged and interactions that can occur between modeled elements in separate HLA-enabled simulations. The Space Reference FOM specifies space-unique data and interactions, and has been developed by an international M&S community.* *Ref: https://www.sisostds.org/StandardsActivities/DevelopmentGroups/SRFOMPDGSpaceReferenceFederationObjectModel.aspx*
GMS 28	*For simulations that involve model object code linked together from disparate sources, participating models shall satisfy the Functional Mockup Interface 2.0 standard. (Ref: https://fmi-standard.org)* *Rationale: FMI is an open, international standard that allows pre-compiled object code from multiple sources to be linked into a common executable. Models may be delivered without delivering associated source code. The reference platform for FMI is Linux and supported languages include C and C++.*
GMS 29	*L3 Element cross-program M&S shall be developed by each of the L3 Elements to support planned systems engineering performance analysis.*

	Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated simulation for systems engineering performance analysis.
GMS 30	*L3 Element cross-program M&S shall be developed by each of the L3 Elements to support flight software development activities.* *Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated simulation for flight software development.*
GMS 31	*L3 Element cross-program M&S shall be developed by each of the L3 Elements to test element interfaces and functional performance.* *Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated testing of interfaces and functional performance.*
GMS 32	*L3 Element cross-program M&S shall be developed by each of the L3 Elements to perform integrated V&V analysis.* *Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated verification and validation testing*
GMS 33	*L3 Element cross-program M&S shall be developed by each of the L3 Elements to perform mission planning analysis.* *Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated simulation for mission planning analysis.*
GMS 34	*L3 Element cross-program M&S shall be developed by each of the L3 Elements to support crew and flight controller training activities.* *Rationale: To support cross-program M&S needs each of the L3 Elements must provide models, simulations and data, to enable effective emulation of element interfaces and functionality. These element M&S will be used to build the L2 integrated simulation in support of full stack, integrated simulation for integrated training activities.*
GMS 35	*The Gateway Modeling and Simulation Working Group shall establish a list of models deemed necessary to share between Gateway elements and recommend contractual requirements to be imposed on element providers.* *Rationale: Contractual requirements are necessary to ensure that models are developed effectively and efficiently through the life cycle of the elements. With specific contractual terms, third-party organizations are required to track the development of space equipment and model its capabilities, often without direct access to detailed design data, at great expense.*
GMS 36	*Each element shall provide models of the behavior of each of its systems, including nominal and off nominal scenarios and associated data to the program for incorporation into integrated vehicle simulations.* *Rationale: Integrated vehicle simulations including for example, propulsion, power, thermal, crew systems, crew health & performance, and life support system models are used throughout the programmatic life cycle for systems engineering, analysis and design, test and verification, training, and mission operations. Models that support integrated vehicle simulations (see definition in section A2.0 Glossary of Terms) are capable of properly propagating behaviors across element and subsystem boundaries.*
GMS 37	*Each element shall provide models of the geometry and dynamics of the system, including nominal and off nominal scenarios, for incorporation into integrated vehicle simulations.* *Rationale: Data is needed to assess integrated performance including geometry models for various analyses. For example, contact and alignment data is needed to assess integrated performance including geometry models for various line-of-sight analyses. Models that support integrated vehicle simulations (see definition in section A2.0 Glossary of Terms) are capable of properly propagating behaviors across element and subsystem boundaries.*

GMS 38	*Each element shall update its delivered models in the L2 repository prior to the start of integrated analysis, verification and operational cycle activities with any mid-cycle release requirements accommodated by agreements between stakeholders.* *Rationale: The proposed design of the vehicle will change throughout its development, and the delivered models need to be updated to support integrated vehicle studies in support of analysis cycles*
GMS 39	*Each element shall produce an emulator that satisfies its data interfaces to other elements and exchanges realistic data with those elements.* *Rationale: Element emulators provide the functionality and data interfaces necessary to support verification of the interfaces and the integrated performance of the vehicle stack before deployment. It is best practice to establish the emulator development early in the program lifecycle to support development of flight software as well as testing of interfaces between systems.*
GMS 40	*Each element shall deliver a copy of its emulator to each element plus one to the program.* *Rationale: At a minimum, each element requires an emulator of its adjacent elements in order to test its interfaces and supporting functionality. The program requires a complete set of emulators to evaluate the complete vehicle stack interfaces and functionality*
GMS 41	*Each element shall keep its delivered emulators up to date throughout the program lifecycle.* *Rationale: The data interfaces and functionality of the vehicle represented in the emulator will change frequently throughout the vehicle development. Updating the emulators helps to identify problems in inter-vehicle interfaces and functionality as early as possible.*